MANUFACTURING PROCESS IN METALLURGY

POWDER METALLURGY

1. POWDER CONDITIONING/TREATMENT & HANDLING.

2. PYROPHORICITY AND TOXICITY OF POWDERS.

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POWDER CONDITIONING/TREATMENT & HANDLING:

In powder conditioning, the powders prepared by various methods are subjected to a variety of treatments involving mechanical, thermal or chemical treatment to improve or modify their physical or chemical characteristics. Powder size, shape and surface conditions have a significant influence on the subsequent processing such as compacting and sintering.

Powder treatments:

Powders manufactured for P/M applications can be classified into two groups: elemental powders, and prealloyed powders.
Elemental powders refers to powders of a single metallic element; e.g. iron for magnetic applications, or mixed with other elemental powders to form an alloy during sintering.

Prealloyed powders refers to more than one element; made by alloying elemental powders during manufacturing process itself. In this case, all the particles have same nominal composition and each particle is equivalent to small/miniature ingot.

Depending upon the nature of powder, whether elemental or prealloyed, and type of application, powders are subjected to variety of treatment.
Majority of powders undergo one or more treatments prior to compaction like:

1. Washing, cleaning and drying to remove moisture.
2. Grinding/crushing to obtain fine sizes.
3. Particle size classification to obtain the desired particle size distribution.
4. Mixing and blending of powders.
5. Lubricant addition for powder compaction,
6. Annealing to improve compaction.
7. Powder coating
1. CLEANING OF POWDERS:

- Refers to the removal of contaminants, solid or gaseous, from the powder particles depending of its applications.

- Solid contaminants => come from several sources like nozzles (in atomization) or crucible linings. They interfere during compaction and sintering preventing proper mechanical bonding. These refractory particles (non-reactive) acts as sites for crack nucleation and adversely affect the dynamic properties of the sintered part. Non-metallic solid impurities can be removed from super-alloy powders by particle separators, electrostatic separation techniques.
• Gaseous impurities like hydrogen and oxygen get into powders during processing, storage or handling, if proper care is not taken. Finer the powders, contamination will be more because of large powder surface area.

• These gaseous impurities can form undesirable oxides during processing at relatively high temperature or gets trapped inside the material as pores, reducing the in-situ performance of the P/M part. Degassing techniques like cold and hot static degassing or cold and hot dynamic degassing methods are used to remove adsorbed gases from the powders
Lubricants added to the powders for better compaction has to be removed prior to sintering, otherwise it will create problem during sintering.

2. GRINDING:

The primary aim of grinding is comminution of powders. Similar to the mechanical methods used in powder production methods, milling is widely used for reducing the aggregates or agglomerates of powder. Milling time, milling speed, or type of milling (wet or dry) can be selected for getting required degree of grinding.
3. POWDER CLASSIFICATION & SCREENING:

Powder size and shape, size distribution varied within specified range is required for better behavior of P/M parts. For example, in the case of porous filters or porous bearings, it is necessary to control the particles size within a very narrow size range. Powder production methods gives a wide band of particle size distribution. These variation depends on one lot to another lot also. These variations can lead to variation in properties of the powder and sintered products. In classification and screening methods, the desired particle size distributions with particle sizes within specific limits can be obtained.
4. BLENDING & MIXING:

Blending and mixing of powders ensure a uniform distribution of different constituents like powders, additives, and lubricants, and facilitate good compaction and sintering particularly if the application involves a multi-component system.

**Blending** is the process in which, powders of the same chemistry but having different particle sizes are intermingled. This is done to:

(i) obtain a uniform distribution of particle sizes, i.e. powders consisting of different particle sizes are often blended to reduce porosity, and
(ii) for intermingling of lubricant with powders to modify metal - powder interaction during compaction and facilitate the compaction.

**Mixing** is the process of combining powders of different chemistries to produce alloys, which would be difficult to produce by other methods such as elemental powder mixes (Cu - Sn) or metal-non-metal powders (e.g. friction materials). The process imparts specials physical & mechanical properties through metallic alloying. In mixing, additives like graphite, binders and lubricants are also added to obtain a homogeneous mixture.
Lubricants are mixed to improve the powders flow characteristics. Binders such as wax or thermo-plastics polymers are added to improve green strength of compacted products. In case of mixing of two or more metal powders, particle characteristics such as size and size distribution play a role in influencing the degree of mixing. Mixing may be done in dry or wet condition. Wet mixing is used to produce a more fine and uniform mixture of powder particles. Liquid medium like alcohol, acetone, benzene or distilled water are used as milling medium in wet milling. Ball mills or rod mills are employed for mixing hard metals such as carbides.
Factors affecting mixing:
1. Type of mixer (V-type, double cone or cylindrical)
2. Volume of the mixers
3. Construction material and surface finish
4. Volume ratio of components
5. Volume ratio of mixers
6. Type of powders and their characteristics
7. Time of mixing
8. Temperature of mixing
9. Type of mixing (wet or dry mixing)

Particle characteristics also affect the mixing characteristics of powders, which are:

(i). The specific gravity of the component powder.
(ii). Particle sizes of individual components. (iii). Particle shape and structure. (iv). Particle surface condition.
Mechanism of mixing:

The various types of mixing methods are,
(i) convective mixing: transfer of one group of particles from one location to another,
(ii) diffusive mixing: movement of particles onto newly formed surface,
(iii) shear mixing: deformation & formation of planes within the powders.

Depending on the extent of mixing, mixing can be classified as (i) perfectly mixed or uniform mixing, (ii) random mixed, & (iii) totally un-mixed. Blending and mixing time should be optimal.
Excess time may lead to demixing or over mixing. Over mixing results in an increase in the apparent density, decrease in flow characteristics of the mix and decrease in green strength of compact. The mixing should be stopped when random mixture is achieved. Over-mixing leads to reduced flow characteristics of the mix.
5. LUBRICANT ADDITION:

The main function of lubricant is to minimize the inter-particle friction as well as friction between powders and the die walls/core rods. This helps to obtain a uniform and desired density in the compact. Lubricants should attach themselves strongly to the metal surfaces and are not easily penetrated in the pores of powders.

Generally, the amount of lubricant added during blending or mixing should not exceed more than 2% by weight of the charge. Large and complex shapes require more amount of lubricant to facilitate easy removal of the green compact. Lubricants are usually added as a fine powder &
mixed with the metal or alloy powders. Lubricants helps to achieve the required green strength and controlled porosity in the finished product. Without proper lubrication, the pressure necessary to eject the compact from the die would be very high and may lead to cracking of the compact. Lubricants also prevents die wear and decrease in operational costs. Type and amount of lubricant must be decided properly to avoid problems during further processing. The green strength as well as sintered part will be affected badly if any residue is left in the products. Lubricants can cause problems like blistering and carburizing of parts.
Mostly Zinc stearate, stearic acid, lithium stearate, and synthetic waxes are used as lubricants. The effect of % lubricant on green density and ejection pressure is shown in figs.
6. HEAT TREATMENT (ANNEALING) OF POWDERS:

Heat treatment is generally carried out before mixing or blending and pressing of the metal powders. Some of the important objectives are:

i) **Improving the purity of powder:** Reduction of surface oxides from powders by annealing in hydrogen or other reducing atmosphere. Dissolved gases like hydrogen and oxygen as impurities are removed by annealing of powders, which are produced by atomization, reduction and electrolysis processes. Removal of carbon in iron powder is done by combustion.
Lowering impurities like carbon results in lower hardness of the powder and hence lower compaction pressures & lower die wear during compaction. For e.g., atomized powders having a combined carbon and oxygen content as high as 1% can be reduced after annealing to about 0.01% carbon and 0.2% oxygen. Heat treatment is done at protective atmosphere like hydrogen, vacuum.

ii) **Improving the powder softness:**

The purpose is to reduce the work hardening effect of powders that has be introduced in the metal powder fines during production by milling, crushing or grinding of bulk materials.
Powder particles are annealed under reducing atmosphere like hydrogen to eliminate the effect of work hardening. The annealing temperature is kept low to avoid fusion of the particles.

iii) Modification of powder characteristics:
    The apparent density of the powders can be modified to a higher or lower value by altering the temperature of treatment. This treatment results in a change in the pressure required for compaction.
7. POWDER COATING:

Coating of metal powders is done in number of cases e.g. coating of cobalt layer on tungsten carbide particles by ball milling. A uniform coating can also be done by electro-deposition process by controlling voltage, time and bath concentration. Coating on metal powder can also be done by electroless process using suitable reducing agents e.g. sodium borohydride is coated on nickel powder. Hydrometallurgical process can also be used for coating a variety of powders with nickel, cobalt or copper.
PYROPHORICITY AND TOXICITY OF POWDERS:

1. Pyrophoricity:
   It is the susceptibility of metal powder for rapid oxidation and may some time catches fire during poor storage environment. This depends upon chemical and physical characteristics of powders such as composition, size and surface area. Aluminium, iron and magnesium are highly pyrophoric in nature, whereas copper and tungsten are not. Certain metals do not need oxygen to burn. Alkali metals like lithium can react with water to liberate hydrogen and sufficient heat, which would cause explosion.
Hence, it is important to follow certain precaution while storing and handling powders with high pyrophoricity. These are as follow:

1. To provide appropriate fire extinguishers like dry sand, dry sodium chloride or soda ashes.
2. In storage tank, unoccupied volume should be filled with inert gases like nitrogen, helium or argon.
3. Use of moisture free processing atmosphere.
4. Use of fire proof enclosure free from oxygen.
5. Use of non-sparking tools during operation.
6. Combustible materials should not be present.
7. All processing should be done under inert atm's.
2. TOXICITY:

- Toxicity leads to undesirable health effects due to skin contact, inhalation or ingestion like irritation of eye and skin to nausea, vomiting, respiratory problems, blood poisoning etc.
- Powder like lead, nickel and beryllia are highly toxic and Aluminium & iron are less toxic.

Precautions: Use of protective gear, gloves, respiratory masks, protective clothing and shoes etc.; respiratory devices such as respirators, suitable first-aid, medical facility, use of well ventilated storage/workplace; careful handling/disposal of fines, effluents or waste fluids.
Important data relating to flammability & reactivity of powders should be available in the plant. In case of any problems, following remedial measures are to be taken:

• **Health effects:** Inhalation of fine powders disturbs the respiratory track. Remedial measures include moving the person to fresh air. Artificial breathing is required if patient does not breathe properly like oxygen, and medical treatment.
• **Skin/eyes:** May cause eye/skin irritation. Brushing the powder off the skin & washing skin with soap. In case of eyes, flush with excess of water for 15 minutes. Medical attention must be given immediately.

• **Ingestion:**

Toxicity of single dose orally is low. It does not cause injury. The person should be taken to hospital for medical treatment.